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No. 431

TESTS ON THRUST AUGMENTORS FOR JET PROPULSION

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SUMMARY

This series of tests was undertaken to determine how much the reaction thrust of a jet could be increased by the use of thrust augmentors and thus to give some indication as to the feasibility of jet propulsion for airplanes. The tests were made during the first part of 1927 at the Langley Memorial Aeronautical Laboratory. A compressed air jet was used in connection with a series of annular guides surrounding the jet to act as thrust augmentors. The results show that, although it is possible to increase the thrust of a jet, the increase is not large enough to affect greatly the status of the problem of the application of jet propulsion to airplanes.

INTRODUCTION

Propulsion of aircraft by means of a jet of burned gas has been the subject of some experiment and still more speculation for a number of years. The simplicity, in its essentials, of this type of prime mover is its most tempting feature. The chief difficulties which it presents are lack of materials to withstand the temperatures encountered, and poor efficiency on account of the high discharge velocity of the jet. Owing to this high velocity, a comparatively small momentum, or thrust, is obtained for a given amount of kinetic energy in the jet. If, however, some of this kinetic energy could be transmitted to the surrounding air in such a way as to reduce the velocity and increase the momentum of the jet, the thrust and consequently the mechanical efficiency of the jet as a propelling unit would be increased. There has been some argument whether augmentors, i.e., Venturi tubes or vanes designed to act on the air surrounding the jet, could increase thrust in this manner. Theoretical considerations give no assurance that any exchange of energy will not be according to the

law of conservation of momentum, with no resulting increase in thrust.

The mathematical study of jet propulsion for airplanes (reference 1) indicates that to be feasible the thrust of the jet would have to be increased several times by the use of thrust augmentors. The present series of tests was undertaken with the object of determining how much, if any, the static thrust of a jet could be increased by their use, and thus give some indication as to the feasibility of jet propulsion for airplanes. It was not possible for the authors to find the results of any previous tests, if any have been made, but some rough sketches of a device for augmenting the thrust of a jet were found in connection with a system of jet propulsion proposed by Melot. (Reference 2.) The device consists of a series of annular guides of curved profile surrounding the jet, the last and largest of which has a diverging cone attached to it making it the shape of a Venturi tube. The action of the jet in passing through the large Venturi is supposed to cause a region of low pressure near the mouth of the Venturi into which the surrounding air is drawn. The vanes and converging part of the Venturi then act on this inflowing air in such a way as to give a reaction which augments the thrust.

In the proposed systems of jet propulsion the jet is composed of products of combustion at a high temperature. In the present experiments compressed air at ordinary temperatures was used inasmuch as a large supply of it was available at the Langley Memorial Aeronautical Laboratory, and because it was believed that the effect of the augmentors would not depend to any large extent upon the temperature and the nature of the gas in the jet. The augmentor was constructed as nearly as possible like the one shown in Melot's sketches. This augmentor and several modifications of it were tested by weighing the reaction of the jet with the augmentor in place and comparing it with the reaction of the jet alone.

METHODS AND APPARATUS

The apparatus is shown in the photograph. (Fig. 1.) A large quantity of air was already available at a high pressure from the variable-density wind tunnel. The air was supplied to a small air chamber through a valve and a flexible hose. The chamber, which was equipped with a

pressure gauge and nozzle, was mounted on a balance for weighing the thrust. The augmentor consisting of three small spun copper vanes and a large Venturi tube surrounding the jet was also mounted on the balance. A sketch of the chamber, nozzle, and thrust augmentor is drawn to scale in Figure 2.

The experiments consisted of weighing the thrust of the free jet and of the jet with various forms of augmentors in place. Readings were taken at several chamber pressures ranging from 25 to 200 pounds per square inch. A run at a pressure of 185 pounds per square inch (200 absolute) was included in each test because the converging-diverging nozzle was designed to expand the air from this pressure to atmospheric pressure at the mouth. Tests were first made with the Melot type of augmentor as shown in Figure 1. The three small spun copper vanes were then removed and tests made with the large Venturi alone. Readings of thrust were also taken with the large Venturi at different heights above the nozzle. The large metal diverging cone was then removed and tests made both with and without the three small augmentors. Besides these tests on the original apparatus a new diverging cone having about the same length but twice the divergence angle was constructed and tested in combination with the original augmentors. A second converging part of the large Venturi having easier curves and a smaller throat diameter (fig. 2) was also constructed and tested with the original diverging cone, both with and without the small augmentors in place.

RESULTS AND DISCUSSION

The results of the tests are presented graphically in Figure 3, where the thrusts of the several combinations tested, expressed as ratios to the theoretical thrust of the free jet, are plotted against chamber pressures. It will be seen that the Melot type of augmentor gave the highest thrust of any of the systems tested. The large Venturi of this system, without the small copper pieces, showed the next highest thrust. This Venturi was also tested at various heights above the mouth of the jet to determine the effect of the spacing on the resulting thrust. No important variation in thrust was found for distances from the nozzle to the bottom of the Venturi varying between two inches and nine inches. A spacing of 6 inches, which is approximately that used in the Melot system, gave slightly better results than any other.

The thrust with the long-throat Venturi used as an augmentor is also plotted in Figure 3. It shows a smaller augmentation over the entire range than either of the above arrangements.

A test was also made using the original throat and a discharge cone having about twice the diverging angle of the original cone. It was hoped that this would give good results without the necessity of such a long cone. The results, however, showed a lower thrust for this system than for the free jet, probably because the diverging angle was too great for the air to follow.

The points spotted in Figure 3 for the Melot type without the diverging cone, and for the large throat only, show that while the small copper augmentors had some beneficial effect, the greater part of the thrust increase is obtained from the Venturi action of the diverging cone.

The curve for the free jet given in Figure 3 shows that the efficiency of this jet is poor for pressures below 100 pounds gauge, but reaches a nearly constant value of 90 per cent of the theoretical thrust of an ideal nozzle for pressures between 100 and 200 pounds gauge.

The curve for the Melot type augmentor, on the other hand, shows that the thrust of the system is greatest as compared with the theoretical thrust of the free jet when the reservoir pressure is considerably lower than the design pressure for the nozzle. In fact, the curve indicates a minimum near 185 pounds per square inch gauge, the design pressure for the nozzle. It is probable that the nozzle did not diverge sufficiently at this pressure to make the Venturi operate to advantage.

Each set of conditions probably requires a different form of nozzle as the highest jet velocity is not obtained unless the nozzle expands the jet to the pressure of the surrounding air. With the Melot type augmentor in place the pressure of the air around the mouth of the nozzle is considerably lower than normal atmospheric pressure because of the high inflow velocity. Therefore at the higher pressures the jet is not sufficiently expanded to give the maximum velocity and thrust. However, at the lower pressures the expansion of the jet within the particular nozzle used becomes sufficient, which probably accounts for the maximum thrust occurring at these pressures. It is therefore probable that by redesigning the nozzle the maximum augmentation could be realized at any desired pressure.

CONCLUSIONS

These results show conclusively that it is possible to increase the thrust of a jet by use of suitably designed augmentors. As the measurements were taken with a stationary jet no indication of the mechanical efficiency of the system as a prime mover was obtained. It is safe to assume, however, that the augmentors would improve the efficiency of any high-speed jet at forward velocities now obtainable in aircraft.

It is not claimed that the systems used give an accurate indication of the maximum possible augmentation of thrust. A better design of augmentor, or the effect of the higher velocities and temperatures of a jet of burned gas, might lead to much better results. However, it is not likely that the large increase mentioned in reference 1 as necessary to the successful application of jet propulsion to aircraft can be obtained.

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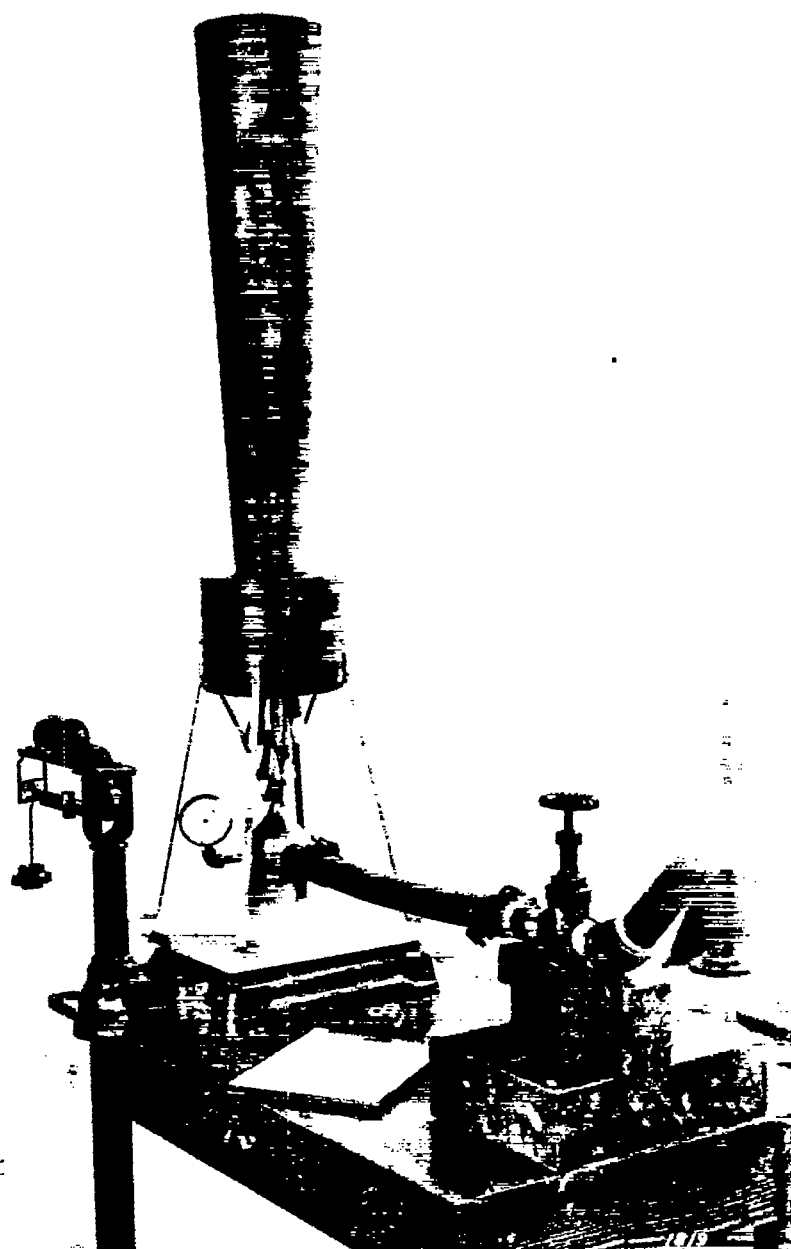


Fig. 1 Apparatus for testing thrust augmentors.

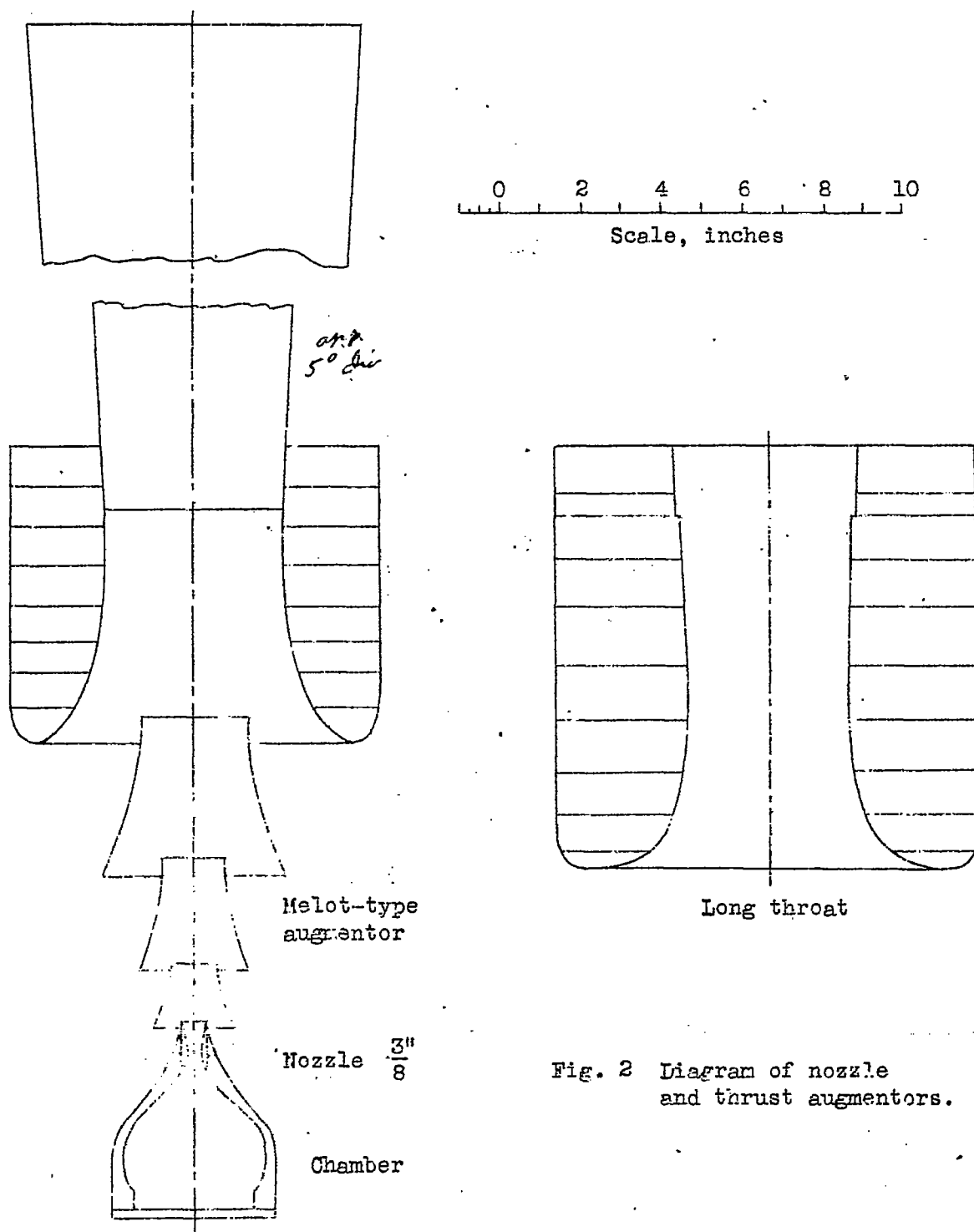


Fig. 2 Diagram of nozzle and thrust augmentors.

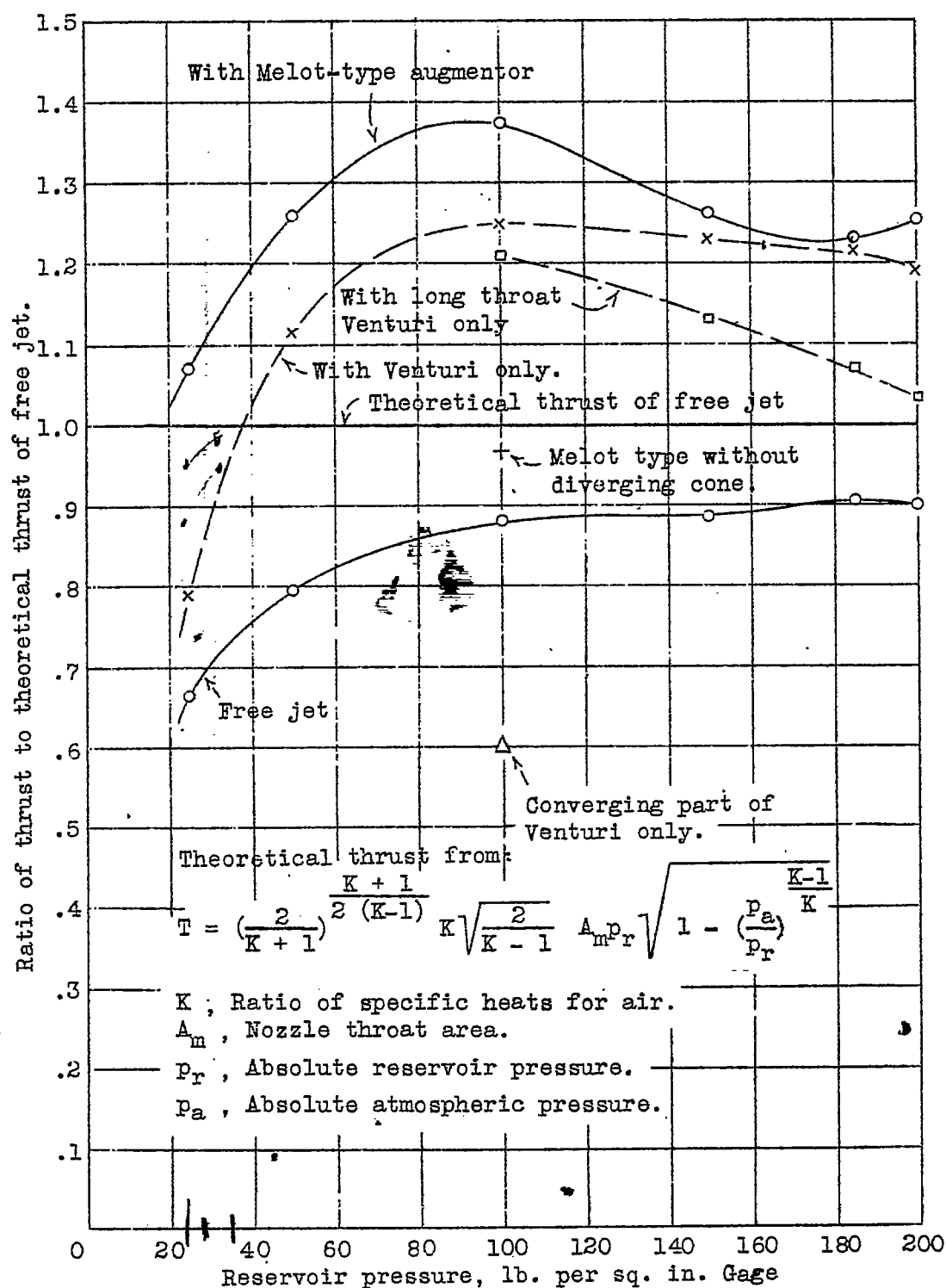


Fig. 3 Thrust for free jet and jet with various augmentors.